COL 786 - Advanced Functional Brain Imaging
Assignment-2 and Assignment-3

Due Date: 7:00pm on Wednesday, 19th March, 2025

Assignment 2

Max Marks : 100

Notes:

- The objective of this assignment is to:
  1. Make you learn how to use the FSL tool to perform all the preprocessing and GLM analysis for a single subject.
  2. Make you learn how to perform linear registration of images to a standard atlas through the command line interface.
  3. Let you explore brain regions involved in language processing and motor functions, through the following stimuli: *video_sentence*, *video_left_hand*, *video_right_hand*, *audio_sentence*, *audio_left_hand*, *audio_right_hand*, *vertical_checkerboard* and *horizontal_checkerboard* using the **Brainomics/Localizer** database (*Orfanos, D. P., Michel, V., Schwartz, Y., Pinel, P., Moreno, A., Le Bihan, D., Frouin, V. (2017). The brainomics/localizer database. Neuroimage, 144, 309-314.*).
  4. Learn about how to use contrasts and fMRI analysis methods to draw suitable scientific conclusions about the brain function.
- The assignment is to be done individually.
- You are required to submit a report containing
  1. Figures of selectively activated brain regions obtained using fslview/fsleyes for each of the tasks and contrasts. The figures should highlight the main areas of the brain found active, similar to the Figure 5 of the paper *Pinel, P., Thirion, B., Meriaux, S., Jobert, A., Serres, J., Le Bihan, D., ... Dehaene, S. (2007). Fast reproducible identification and large-scale databasing of individual functional cognitive networks. BMC neuroscience, 8(1), 1-18.*
  2. Tables similar to Table 2 of the above paper.
  3. Your comments on whether the activations found by you are consistent with your expectations. Try to write your results in the form of a short paper. The evaluation will be based on the quality of your writeup, not on the number of words used.
  4. Link to the google drive directory containing all your scripts and results. Include a README.txt file in the directory that describes the file names for the preprocessed data and registered (non-thresholded) zstat maps. Do not include any data/files in your submission.

  The report is to be submitted on Gradescope before the due date.
- There may be a demo of your assignment, but the assignment will primarily be evaluated based on the quality of your report. You may be notified about the demo later.
- Upload your final directory containing all your results and the design.fsf files and all your scripts (if any) in a google drive folder and submit a readable link in your report to your folder. **Make sure that you do not change any files in the drive after the assignment deadline. Failure to comply to this instruction, may lead to a disciplinary action.**

- This assignment is divided into two parts. The first part involves single subject preprocessing, GLM analysis of the fMRI BOLD data along with registration of the results obtained to a standard template. The second part requires you to identify the brain regions activated for the contrasts generated in part 1. Finally, you are supposed to present your findings in the form of a report. You need to comment on all the main brain regions that you found to be active in specific task conditions and whether your results are consistent with the prior knowledge on these areas. You are encouraged to take help of Wikipedia, Scholarpedia, google scholar and other online resources to put your results in perspective of the prior knowledge. Give suitable references about prior knowledge in your report justifying the regions found to be active in your analysis.
- The data of this assignment is based on the Brainomics/Localizer database. For more details about the protocol, refer to the following papers.
  - *Orfanos, D. P., Michel, V., Schwartz, Y., Pinel, P., Moreno, A., Le Bihan, D., Frouin, V. (2017). The brainomics/localizer database. Neuroimage, 144, 309-314.*
  - *Pinel, P., Thirion, B., Meriaux, S., Jobert, A., Serres, J., Le Bihan, D., ... Dehaene, S. (2007). Fast reproducible identification and large-scale databasing of individual functional cognitive networks. BMC neuroscience, 8(1), 1-18.*
- The complete data inluding the structural, functional fMRI files and stimulus presentation timings details can be downloaded from this link. Use the following files for structural and functional data.

  fMRI BOLD: `S01/raw_fMRI_raw_bold.nii.gz`

  Structural: `S01/raw_T1_raw_anat_defaced.nii.gz`

  The 3-column EV files for the various stimuli are present in the `metadata` folder and are named as follows:

  audio computation *EV1_audio_computation.txt*

  audio left hand *EV2_audio_left_hand.txt*

  audio right hand *EV3_audio_right_hand.txt*

  audio sentence *EV4_audio_sentence.txt*

  horizontal checkerboard *EV5_horizontal_checkerboard.txt*

  vertical checkerboard *EV6_vertical_checkerboard.txt*

  video computation *EV7_video_computation.txt*

  video left hand *EV8_video_left_hand.txt*

  video right hand *EV9_video_right_hand.txt*

  video sentence *EV10_video_sentence.txt*
- The assignment will take time. Start early. Do not postpone till the last few days.
- For doubts send an email to rahulgarg@cse.iitd.ac.in

1. **Preprocessing and registration [30 marks]** Perform the pre-processing steps using the FSL tool. The pre-processing should include brain extraction, spatial smoothing (4mm FWHM) and temporal filtering (100 seconds high pass), motion correction and linear registration to the standard 2mm MNI brain template. Your submission should include the design.fsf file, the log of FSL runs and the output, intermediate files and/or any other scripts that you may have used.

   Your report for this part should include the screenshots of the GUI tool that where you set different pre-processing parameters. Clearly indicate in your report (using the images) where you have set different parameters. Also include structural and functional brain images before and after brain extraction step, functional images of brain before and after spatial smoothing. Include the time series of (preferably an activated) voxel before and after the temporal filtering and time series of motion corrected in your report. Check the quality of your registration using fslview/fsleyes overlays and re-run with changed parameters if needed. Include the overlaid images of final registration for quality assessment (anatomical to standard, functional to anatomical and functional to standard).

2. **Generating Contrasts [40 marks]**: The following Explanatory Variables (EVs) are used: audio left hand, audio right hand, audio sentence, horizontal checkerboard, vertical checkerboard, video left hand, video right hand, video sentence. The 3-column format files for the EVs are given with the data. You are required to generate the following contrasts and explain (in your report) if your findings are consistent with the existing literature. Also include a graphical representation of your design matrix in your report (similar to design.png generated by FSL). For your figures, include activations as well as de-activations. For your tables, include the coordinates in MNI space and also the brain areas corresponding to the voxel coordinates. Include your zstat.nii files in your final submission.

   (a) video left motor - video right motor

   (b) audio left motor - audio right motor

   (c) (video+audio) left motor - (video+audio) right motor

   Use conjunction of the above three contrasts to find brain areas that are selectively involved in movement of the left hand. Also carry out another conjunction analysis to find brain areas selectively involved in movement of right hand.

3. **Localizing Language Areas [30 marks]**: Design a suitable method to find the brain areas in this person that are selectively involved in language comprehension. You may use any of the analysis methods (subtraction, factorial, parametric, conjunction) discussed in the class.

   In your report, clearly describe your method in detail along with a detailed explanation of why you used that method. Also, in your report include all the intermediate results along with your final results. For example, if you are using factorial method (refer to Figure 2 in Amaro, Barker 2006) with two cognitive components A, B, include brain maps for all the 4 contrasts A - nAB, (A+B) - B, (A - nAB) - ((A+B) - B)). If you used conjunction analysis, include the brain maps for all conditions generated. Your final results must include brain maps as well as tables indicating all the clusters that you found in the standard reporting format (including cluster size, MNI coordinates, brain region etc.).

For parts (2) and (3), you may use a t-statistic threshold of 3 to designate the corresponding voxel as active (i.e., corresponding hypothesis test for the given contrast rejects the null hypothesis).

Assignment 3

Due Date: 7:00pm on Sunday 23^{rd} March 2025.

Max Marks : 100

Part (a) [50 Marks]: The objective of this part of the assignment is to make you learn how to use the FSL tool to perform higher-level analysis across subjects and study the mean group effect, i.e., whether the group activates on average. The same contrasts (as defined in A2, part 2) are to be used for the group analysis. Same conjunction analysis needs to be done for the group contrast. A similar report (as specified in A2) and output files need to be submitted. The data for this assignment is available at the following link. Do not use the data from the original brainomics site as it has some errors that will take some time to fix. The data provided has been cleaned up to avoid any errors.

Part (b) [50 Marks]: Define the language laterality index of a subject as follows:

$$LI = \frac{L - R}{L + R}$$

where L is the number of language voxels activated in the left hemisphere and R is the number of language voxels activated in the right hemisphere. Please see the following paper Measuring language lateralisation with different language tasks: a systematic review for more information on language lateralization. We can also define the laterality at the lobe level. For temporal lobe laterality, L and R will correspond to the active voxels in the temporal lobe of the left and right hemispheres of the subject respectively. The frontal lobe laterality can also be defined analogusly. Use your language localization analysis of assignment 2 to find the laterality indices (frontal lobe, temporal lobe, full brain) of each subject and report your results in your report in the form of a table. Your table should have the following columns: **subject_id, L(temopral), R(temporal), LI(temporal), L(frontal), R(frontal), LI(forntal), L(full-brain), R(full-brain), LI(full-brain)**. Also include a binary mask (nii.gz image) of each subject indicating its voxels selectively involved in processing language in your results directory. Clearly indicate suitable file naming conventions in your report to help identify the corresponding brain masks.

Include a link to the directory with suitable timestamps of all the files used to create your results in your final submission.